

CHAPTER H-5 LEVEE CLOSURE SYSTEMS

H-5.1 Key Concepts

Levee closure systems are usually temporary structures that are put in place at openings along the embankment/floodwall to provide flood protection when the river/stream is elevated. The openings are typically for vehicular, rail, or pedestrian access through the embankment/floodwall when the river/stream is at normal levels (non-flood). A simple example of a levee/floodwall closure is shown in Figure H-5-1 which shows a small gate structure used for pedestrian access.



Figure H-5-1. Example of Levee/Floodwall Closure Structure

There are a variety of levee closure systems in use with each having its advantages and disadvantages. Some types may have higher original construction costs, but may be much easier to manage and set in place when needed. Others may have minimal initial cost, but rely heavily on personnel to successfully implement. The timing of the rise/fall of water levels also plays an important role in deciding which type of closure system is most applicable.



Another special type of levee closure system is culvert/pipe closures. One of the main reasons culverts/pipes are placed in embankments/floodwalls is to remove interior drainage that builds up during rainfall events; however, when the river/stream is elevated during periods of flooding, there needs to be a means to keep backflow from going through the drainage pipe into the landside (protected) side of the levee. There are numerous types of culvert/pipe closures that are used depending upon the operating environment and wide array of other factors.

This chapter will primarily focus on the risk aspects of closure operation. The structural design of closures is governed by general concrete and steel design theory which is covered by other documents including USACE Engineering Manual 1110-2-2502 Retaining and Flood Walls.

H-5.2 Non-Culvert Closure Types

As stated previously, most non-culvert closure types are for the temporary blocking of access openings within embankment/floodwalls during times when the adjoining river/stream is elevated and would flood the interior without the structure being in place. There are numerous types of non-culvert closure systems and each carries inherent risks associated with their successful implementation and operation. While there may be other non-culvert closure systems in existence, the vast majority within the U.S. inventory of levee systems will fall into one of the categories detailed within this chapter.

H-5.2.1 Bulkhead/Stoplog Style Closures

For the purposes of this closure type, the term bulkhead and stoplog are assumed to have the same meaning and are used interchangeably. A bulkhead/stoplog closure is one of the simpler closure types used for embankment/floodwall closures. It usually involves a vertical slot that has been formed into the adjacent concrete section part of either the closure structure or floodwall itself. The stoplogs are then simply lifted into place and vertically stacked upon one another until the desired height is reached for the closure. Figure H-5-2 shows a stoplog closure being placed by maintenance personnel. Bulkhead/stoplog closures are typically used only when the opening itself isn't too wide (less than 8 feet or so) for pedestrian or single lane vehicular/bike access. Wider openings require a supporting structure, such as a frame or vertical post, and are considered under the post/panel closure style.

There are several issues that must be considered when evaluating the risks associated with bulkhead/stoplog closure systems. Experience has shown that the biggest risks associated with these type closures are ensuring all necessary parts are available at the time the closure needs to be set in place and the overall condition of the closure superstructure itself including the sill plate is satisfactory. Several levees utilize a storage building/vault adjacent to or incorporated within the floodwall for storing the closure stoplogs. While this is certainly convenient for both storing the parts and setting the closure, there have been numerous instances where the storage buildings/vaults have been vandalized and the stoplogs stolen or damaged; therefore, it is imperative that these facilities are well secured and the parts are routinely inventoried. This is especially true for rural areas where the vaults aren't located in highly visible areas. When the security of the stoplog storage structure can't be guaranteed, it is recommended that the closure parts be moved to a more secure location.



Figure H-5-2. Setting Stoplog Closure

In terms of structural condition, the stoplogs will usually be set within a concrete structure that is used to transition between the closure and adjoining embankment or the floodwall itself. The condition of the slots (bearing surface) for the concrete structure and the sill itself must be able to safely withstand the forces for which it is required to carry. This means there should be no significant structural cracking of the bearing areas and the sill plate provides an even surface for bearing the vertical weight of the stoplogs. This is especially true for instances where the sill plate may have been paved over or otherwise modified in some manner. It is also important to note the condition of the elastomeric seals used for many stoplog closures. These are located between the interfaces of the sill and individual stoplogs themselves. These have a tendency to dry rot over time and can cause operational issues. Finally, sandbags are usually placed around both sides of the sill plate/stoplog interface to help reduce seepage.

Similar to other types of closures covered within this document, it is important that personnel responsible for setting the closure have recent (within last 5 years) experience in successfully doing so as either a practice operation or flood response activity. Not only will this improve the likelihood of successfully installing the closure, but it also helps ensure the parts are inventoried on routine basis.

H-5.2.2 Post/Panel Style Closures

Post and panel style closures are similar to bulkhead/stoplog closures except the panels (vertical or horizontal alignment) require the use of structural support other than the adjacent wall section in order to span a wider opening. The support structure usually comes in the form of a vertical post with accompanying foundation slot or a structural frame. Examples of both of these are shown in Figure H-5-3 (vertical post) and Figure H-5-4 (structural frame), respectively.

Many of the same issues affecting the risk that were discussed for bulkhead/stoplog closures are also applicable to post/panel closures, but to an even greater extent. The installation of post/panel closure structures usually require significantly more parts, manpower, equipment, and time; thus, it is imperative that the closure parts are marked and inventoried on a frequent basis. The same issues with respect to storing the closure parts in a safe location apply to this closure type as well. The sequence of installation for post/panel closures is even more critical when compared to stoplog closures. Premature tightening of the connections can lead to misalignment problems. It

is also important that the closures are set on a routine basis so when a flood occurs, the personnel setting the closure have recent experience in setting it successfully and are fully aware of the time requirements to do so. Post/panel closures typically come with an installation manual to assist with the erection procedure (or they are part of the project's operation/maintenance manual). When personnel experience is limited or there are numerous closures on a levee system, having an updated installation manual plays an important role in the likelihood of successfully setting the closure correctly.



Figure H-5-3. Installation of Post/Panel Closure Utilizing Vertical Support Posts



Figure H-5-4. Setting a Post/Panel Closure with Supporting Frame

Another significant concern with respect to both stoplog and post/panel closures is the condition of the bearing sill. There are many instances where the sills have been severely damaged from a combination of traffic, weathering, and road changes/maintenance. Figure H-5-5 shows a deteriorated sill structure for a combination railroad and road post/plane closure. There have been numerous cases where it has been so long since the closure was set that the bearing sill has been paved over and is no longer visible. The condition of the bearing sill should be included as part of the overall assessment of the closure superstructure when assessing the risk of these features.



Figure H-5-5. Deteriorated Bearing Sill for Combination RR and Road Closure

The USACE Levee Screening Tool (LST) is a risk assessment tool that has been developed to assist with initial risk screenings of over 3,500 levee segments as part of the USACE Levee Safety Program. One of the performance modes evaluated within the LST is levee closure systems. A supplemental assessment module requires a LST screening team to provide performance ratings for the various types of closures that exist within the levee segment. The ratings selected by the team provide an indication of relative performance risk associated with the type of closure. Bulkhead/stoplog and post/panel closures are evaluated using the same analytics within the LST since their performance is influenced by the same factors. These factors are depicted in Table H-5-1 for bulkhead/stoplog and post/panel closure systems.

Table H-5-1 Assessment Rating Categories for Bulkhead/Stoplog and Post/Panel Closures

CATEGORY	INFLUENCE ON PERFORMANCE		
	Positive (+)	Neutral	Negative (-)
STORAGE AND SECURITY	Parts are stored in the interior of a locked building within a secure area. Threat of vandalism or theft is highly unlikely. Parts have been inventoried within the last year.	Parts are stored in a less secure fashion than noted under the 'Positive' rating <u>AND</u> the parts have been inventoried within the last year <u>OR</u> parts are stored in a secure fashion <u>AND</u> they have been inventoried within the last 5 years.	Part are stored in an unsecured fashion and there is a history of theft/vandalism associated with storage structure <u>AND</u> parts haven't been inventoried within the last year.
OPERATING PLAN AND EXPERIENCE	There is a well documented plan <u>AND</u> personnel have set closure successfully within the last 5 years.	Personnel have successful experience in setting closure within the last 5 years <u>OR</u> there is a well-documented plan for the closure structure.	Personnel are inexperienced in successfully setting the closure <u>AND</u> there isn't a well-documented installation plan available.
CONDITION OF THE CLOSURE STRUCTURE	Both the overall closure superstructure and parts are in good condition <u>AND</u> have been loaded to at least 50% of closure height in the past.	Both the overall closure superstructure and parts are in good condition but the closure has never been loaded more than 50% of its height.	Closure superstructure or parts are in a deteriorated condition <u>AND/OR</u> performance issues have existed in past while loaded and hasn't been rectified since the issue occurred.
MISCELLANEOUS ISSUE	There are no miscellaneous issues that will adversely impact the ability to successfully set the closure or impede its operation once set in place.	There is a miscellaneous that exists, but it is unlikely to adversely impact the ability to successfully set the closure or impede its operation once set in place.	There is a miscellaneous issue that has a reasonable likelihood of causing the performance issues either with setting the closure or with its operation once set.

H-5.2.3 Moveable Gate Closures

Moveable gate closures are usually the simplest type of non-culvert closure to set. They are gate structures that are moved into place by either manual or mechanical means. The gates are permanently attached to the closure superstructure (adjacent closure wall section) in the recessed or open position and then simply moved into place ahead of the rising floodwaters. Once moved into their final position (recessed or closed), they are secured by some type of locking mechanism so they don't move. There are a variety of styles of moveable gate closures (overhead trolley rolling, roller, and swing gates are typical). An example of each type is shown in Figures H-5-6 through H-5-8.



Figure H-5-6. Overhead Trolley Rolling Gate Closure for Floodwall

Based upon historical performance data collected and analyzed for the USACE levee portfolio, moveable gate closures are considered the most reliable type of non-culvert closure. This is because they are easy to set, require no inventory of parts, and can quickly be moved into place by maintenance personnel. The primary reason they aren't used more frequently is because of the high initial cost to construct the gate and supporting closure structure. Not only does the heavy steel gate require a higher initial cost, but the wall, any supporting frame (overhead trolley slide gates), and sill structure must be designed into the closure structure as well. This increases the initial construction costs considerably when compared to using other types of closure systems.

The most influential risk factor affecting the ability to successfully set moveable gate closures is the operating plan and experience. Moveable gate closures are frequently used in urbanized areas where there are numerous closures that have to be set in place ahead of rising floodwaters. Sometimes different entities are responsible for setting different closures; therefore, it is imperative that there is a well understood operating plan for the “who, what, and when” of how each closure is to be set within a levee system. Other less influential risk factors include vandalism and general structural condition; however, most of the moveable closures are in highly visible, urbanized areas and are less susceptible to vandalism. The general structural condition can easily be checked as part of an active inspection program since the gates are easily accessible

and highly visible. This includes the condition of the seals since they are continually exposed to sunlight and weathering. They should be inspected frequently and replaced when necessary.



Figure H-5-7. Roller Gate at Levee Road Crossing



Figure H-5-8. Swing Gate Closure

H-5.2.4 Sandbag Closures

Sandbag closures are likely the most common type of access closure in existence due to their low cost of implementation and simplicity; however, their use has limited applications. Sandbag closures should only be used when the height of the closure (elevation from base of sandbags to the top) is no more than 4 feet and there is ample time to set the closure. There has to be enough time and enough workers/volunteers to fill the bags, move them to the site, and then set them in place. A typical sandbag closure is shown in Figure H-5-9.



Figure H-5-9. Sandbag Closure at Road Crossing

When assessing the risk of successfully placing a sandbag closure, the most important consideration is the operating plan and experience of the personnel responsible for setting the closure. Sandbag closures take time to set so they should never been used when the river rises and falls quickly which is typical for creeks, streams, and rivers in moderate-to-steep terrain. There simply isn't enough time to mobilize individuals, fill the bags, and place them when the rise of the river occurs within hours as opposed to days/weeks. They are more applicable for large rivers that rise and recede relatively slowly (days-to-weeks).

Many times volunteers are building the sandbag closure, so another important factor associated with the operating plan/experience is the manner in which it is constructed. Someone with experience or knowledge should direct others if inexperienced individuals are setting the closure. An example of the incorrect placement of sandbags is shown in Figure H-5-10 where volunteers are simply increasing the height by throwing bags on a pile. If loaded significantly, this sandbag wall most likely won't hold back the floodwaters. The sandbags should be placed in an interlocking fashion for stability. There has to be sufficient base width in order to build the sandbag pyramid to ensure its stability. This is particularly important for taller (greater than three feet) sandbag closures. Figure H-5-11 shows sandbag placement guidelines for varying heights up to four feet. There also has to be an ample supply of bags and sand available since these

sandbags aren't stored with sand in them as they will deteriorate the bags over time. The following is an approximate estimate of the supplies needed for various sandbag closure heights:

- 1-ft tall: 600 bags, 17 cubic yards (cy) of sand
- 2-ft tall: 2,100 bags, 59 cy of sand
- 3-ft tall: 4,500 bags, 126 cy of sand
- 4-ft tall: 7,800 bags, 218 cy of sand

Sandbag closures aren't recommended for closures taller than 4 feet



Figure H-5-10. Incorrect Placement of Sandbags

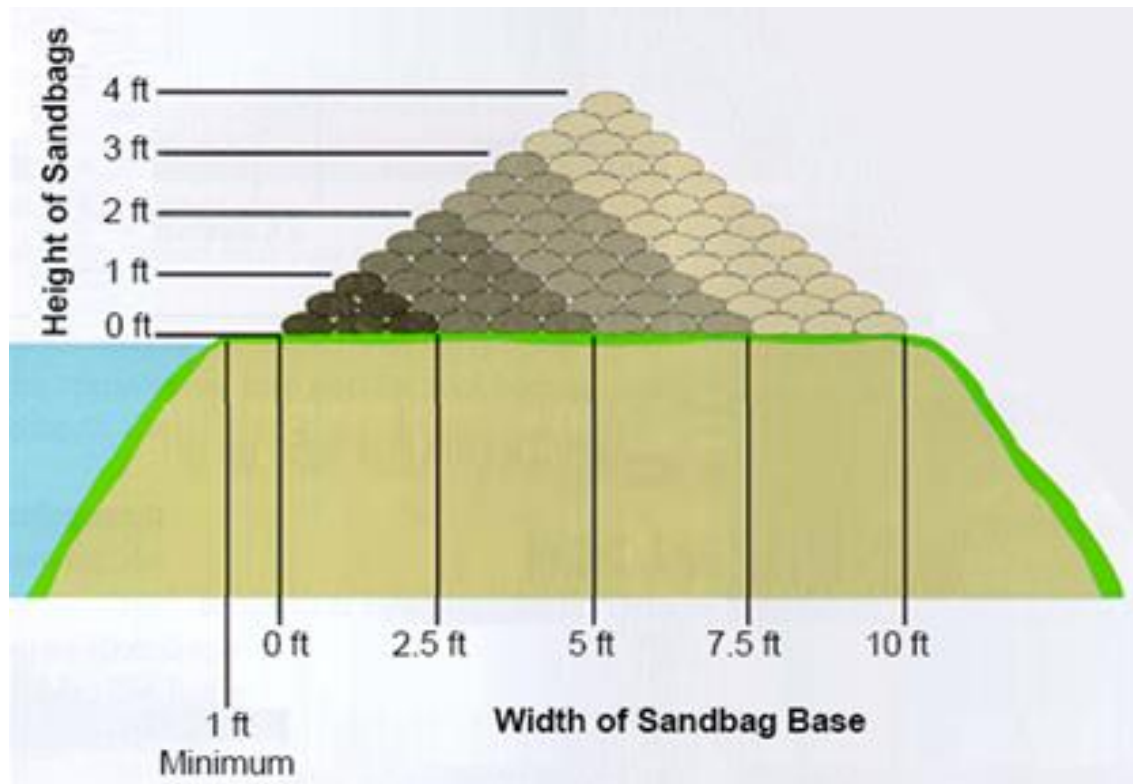


Figure H-5-11. Sandbag Placement Guidelines

Another risk factor, but typically less influential than operating plan/experience, that needs to be considered with respect to sandbag closures is how the supplies are stored. Similar to bulkhead/stoplog and post/panel closures, sandbag supplies (primarily the bags themselves) need to be stored in a secure, enclosed facility. It needs to be secure so the bags aren't stolen or vandalized. It should be enclosed to help prevent weathering deterioration of the bags themselves. Another issue is the sand itself. There have been documented cases (Smithland, KY, 2008) where the sand used had a significant percentage of fines, and the sand was also wet. The air temperatures were low enough that the bags froze into solid blocks, and thus could not deform in the manner required to provide a tight interlock and seal between bags. The community had to dispose of the frozen bags, thousands of which had been filled by volunteers, because they could not perform their intended function.

H-5.2.5 Soil Piles and Soil Baskets

The final type of non-culvert closure considered within this document is soil pile with plastic sheeting and/or soil baskets. Both of these involve moving soil into place to provide a water barrier. Soil piles covered with plastic can provide sufficient weight and a good enough water barrier for providing temporary closure (Figure H-5-12). An alternative option is utilization of an engineered container system, referred to as soil baskets, one type of which is shown in Figure H-5-13. Soil pile/baskets can be a cost-effective way to set a temporary closure, but caution is warranted. First, heavy equipment should not be placed on a levee when it is saturated. This could cause the levee to fail or be seriously damaged under the additional weight. Soil piles or baskets usually involve the use of heavy construction equipment to move the soil in place in an efficient manner. The required equipment and potential for damaging the levee should be considered when assessing the risk of placing these type closures. Another issue of concern is when soils used to set the closure are taken from the landside slope of an adjacent levee section. This is not recommended and can weaken the levee section where the soil is taken by shortening the seepage path or causing an unstable slope.



Figure H-5-12. Soil Pile with Plastic Sheeting Closure

The most important factor to consider when evaluating the placement of soil pile/basket closures is the experience of personnel setting the closure. This not only relates to how to properly construct the closures, but also knowledge regarding the time and equipment requirements. In lieu of recent experience, a well-documented operation plan should be available for setting these closures, particularly soil baskets. Soil baskets should never be double stacked (on top of one another to increase height) unless they are specifically designed to do so for flood fighting as this can lead to an unstable structure. It is recommended to refer to the manufacturer's installation procedures and instructions to fully understand the system being set in place and the associated limitations.



Figure H-5-13. Soil Basket Flood Barrier under Construction

There are multiple types of soil basket systems and each has their own advantages/disadvantages. Some require specialized equipment specifically for constructing the flood barrier system. It is doubtful these would be part of a designed closure system for levees due to the equipment requirements. Most of these systems use typical construction equipment (front end loaders, etc.) and require a certain number of personnel to set the closure in a timely manner. Special care must be taken to ensure the foundation of the soil pile/basket closure is able to withstand the hydraulic loading. There has been at least one known case history when a soil basket system failed and flooded the interior because of seepage and piping of material below the base of the soil baskets. More information on this is provided in the case histories section of this chapter.

H-5.3 Large Pump Station Closure Structures

These type of closures are significant structural members that are designed to shut off flow through very large openings at high capacity pump stations. These closure structures are

typically large steel gates/bulkheads that are designed as an integral part of a gravity monolith section. They are usually associated with flood protection systems in highly urbanized areas where high capacity pump stations are utilized for the removal of interior drainage. When the river is low, the opening allows gravity flow to remove interior water through the closure bay. When the river is elevated, the large gates/bulkheads are lowered into place and interior drainage is removed via pumping operations. Figure H-5-14 shows the original completed construction of the Mill Creek Pump Station closure bay in Cincinnati, OH. Note the section where the large steel bulkheads are lowered into place through the use of a crane and the adjacent area where the bulkhead are stored.



Figure H-5-14. Mill Creek Pump Station Closure Bay

When assessing the operational risk of these structures, many of the same issues associated with smaller closure types (stoplogs, post/panel) are also applicable to pump station closure bays. This includes the experience of the personnel setting the closure as well as ensuring sufficient time is

available to set the closures in an efficient manner. The potential for debris blockage needs to be considered in both the design and operation of these features. Finally, the overall condition of the gates/bulkheads is vitally important. These structures should be routinely inspected and maintained as necessary including any seals, lifting connections, and sill structures.

H-5.4 Culvert/Pipe Closure Gates

The purpose of a culvert gate closure is to shut off flow from entering the leveed area when water levels rise on the discharge side of the culvert. During normal operation of drainage structures, the gate closure is left open to allow the culvert to drain interior water by gravity; however, when water is high on the discharge (flood) side, the gate closure is shut and interior drainage is usually sent to the flood side by means of a pump station or simply stored in a ponding area on the landside of the levee until the river recedes and gravity drainage can again be used once the gate is opened. The performance of the culvert gate closures is important because if they cannot be shut, the flood waters can enter the land side through the culvert. It is also possible to have a culvert gate closed due to a malfunction such that interior water is unable to be drained through the culvert leading to landside flooding. There are five representative types of culvert gate closures detailed within this document and these cover the vast majority of culvert gate closure systems in use.

H-5.4.1 Culvert Flap Gate Closures

One of the more common types of closures for culverts is flap gates. They are very popular because of their relatively low cost, automatic functionality, and wide range of sizes. Flap gate closures are placed at the outlet end of the culvert and are designed to remain shut at all times; thus, when the river rises above the outlet end of the pipe, it will seal against the end of the pipe and keep water from entering the culvert. When the river is low, their simple design allows interior drainage to discharge through the outlet end by applying a small amount of water pressure from flowing water to “crack” the bottom of the flap gate open, as shown in Figure H-5-15. Once the flow subsides, the valve is designed to close back against the vertical face of the culvert. Sometimes the flap gate may be ‘propped’ open to ensure an obstruction doesn’t block the flap gate in the closed position, such as shown in Figure H-5-16. When this type of system is

used, it is important to realize the flap gate must be manually shut ahead of rising floodwaters otherwise unrestricted flow through the culvert will occur and flood the interior.



Figure H-5-15. Culvert Flap Gate Closure

Typically, the biggest issue that results in a malfunction of a culvert flap gate closure is an obstruction causing the gate being stuck partially open or closed. During periods of flooding, it is common to have increased amounts of debris in the river and there have been numerous instances where debris (tree roots, foreign objects, etc.) has gotten wedged in the flap gate causing it be stuck partially open and allowing the river water to enter through the opening at the end of the pipe. This is one of the primary reasons that many culverts are designed with a secondary means to shut off flow through culvert, such as a sluice gate, as shown in Figure H-5-17. A secondary means of closure is highly recommended especially in urban areas where interior flooding has significantly more consequences than rural areas.



Figure H-5-16. Culvert Flap Gate Modified to Remain Open

There have also been numerous cases where lack of maintenance at the outlet end of the culvert has resulted in the culvert flap gate closure being silted in and unable to drain by gravity which can also lead to interior flooding. In this situation, a secondary means of closure won't alleviate the problem and the obstruction (sediment blocking the flap gate) needs to be cleared in order for gravity drainage to work successfully.

Another concern with flap gate closures is theft. It is not uncommon to have the flap gates stolen and sold as scrap metal. In most cases, flap gates are easily accessible by the public and not difficult to remove with minimal tools. If there is a known history of theft/vandalism of culvert flap gates in the area, it is recommended a different culvert gate closure design be utilized. A secondary means of closure (sluice gate) would also alleviate the potential of flooding if the flap gate is stolen or vandalized.



Figure H-5-17. Culvert with Flap Gate and Sluice Gate Closure

H-5.4.2 Culvert Sluice Gate Closures

Vertical sluice gate closure are another popular means to shut off flow through a culvert. Most sluice gate closures consist of vertical steel gates that are lowered into place by turning a screw stem attached to the sluice gate. Pulley systems are also used in some instances to lower and raise the sluice gate. Sluice gates are installed either at the outlet end of the culvert (as shown in Figure H-5-18) or within a gate well somewhere along the length of the pipe (such as Figure H-5-19). In both situations, someone must lower the gate into place either manually or with the assistance of mechanical equipment. Sluice gates constructed within a gate well are typically placed on the riverside slope of the levee near the crest in order to gain easy access to the gate well. As noted previously, they are used many times in conjunction with flap gates to provide two means to shut off river flow through the culvert.

Sluice gates may be placed at the outlet end of the culvert to keep it from getting significant interior pressure from riverside water levels. When the sluice gate is located along the pipe within a gate well, the pipe itself should be designed for interior pressure applications from elevated river levels.



Figure H-5-18. Sluice Gate Being Constructed at Outlet End of Culvert

The biggest consideration of risk as it relates to sluice gates is condition and maintenance of the sluice gate and screw stem. As part of a USACE in-depth evaluation of levee performance across its portfolio, it has been noted there have been several instances where sluice gates were rendered inoperable because of poor condition (bent screw stem, damaged sluice gate) or lack of maintenance (inadequate greasing of screw stem). This has either led to interior flooding when the sluice gate has been unable to shut or emergency flood fight actions to choke off the flow by either somehow closing off the outlet end or temporarily filling in portions of the gatewell opening with material. When the sluice gate is out the outlet end of the pipe (as shown in Figure H-5-18), personnel responsible for closing the gate must take action before the river rises above the screw stem turning connection.

Sluice gate closures are more robust than simple flap gates, but also require more maintenance and periodic testing to ensure they operate in a variety of climate conditions. They should be operated frequently and well-greased to ensure good performance when needed during a flood event.



Figure H-5-19. View of Sluice Gate Looking Down from Top of Gate Well

H-5.4.3 Duckbill Valves

Duckbill valves are one piece elastomeric devices that act as a check valve (only allow one way flow). They are attached to the outlet end of the culvert to prevent backflow through the pipe. They are referred to as duckbill valves because they resemble the bill of a duck (see Figure H-5-20). Duckbill valves are designed so they are closed when no flow through the pipe is present. Once the culvert starts to receive interior flow, the vertical seal will open under pressure allowing water to drain out of the duckbill and culvert. It usually takes 1-2" of water above the

invert of the culvert in order to crack open the seal of the valve. It is designed to re-seal once the interior water is drained sufficiently. When the river level rises on the exterior of the culvert, the vertical seal is designed to keep exterior water from entering the pipe. Duckbill closure devices have been used successfully in many installations and are a popular option when the theft of flap gates is a recurring problem and in areas where corrosion of steel products could be a significant issue. Generally speaking, they require no maintenance and are quite cost effective compared to other closure features.



Figure H-5-20. Duck Bill at Outlet End of Culvert

When assessing the performance of duckbill valves, there are several issues to consider. First, duckbill valves are more susceptible to damage caused by fast moving debris within the river. If the river or stream under consideration carries a lot of debris in the area where the pipe outlet occurs, other culvert gates may be a better option or the duckbill itself would somehow have to be protected from impacts. Another concern is the potential for a foreign object (such as debris) to get wedged within the bill while it is opened. This would render the duckbill inoperable and unable to prevent backflow. Finally, duckbills are designed to withstand a certain level of damage from sunlight, but over time it is possible that the material can begin to dry out, crack,

and potentially lead to poor performance (unable to re-seal, etc.). This is something to consider when evaluating their long-term performance.

H-5.5 Closure System Case Histories

There have been numerous instances where levee closure systems have either failed to be set for a flood or have failed after being placed. In both cases, the landside (interior) of the levee was flooded as a result of these incidents. A few case histories are included herein for reference.

H-5.5.1 Post/Panel Closure System Case History – Gary North LFPP

The Gary North Local Flood Protection Project (LFPP) is a federally-constructed, locally operated/maintained levee segment located along the Little Calumet River in northern Indiana. The segment is approximately 8.4 miles long (8.0 miles of levee embankment, 0.4 mile of floodwall). It is located in a heavily industrialized area. There are a total of seven different non-culvert closure systems within this segment (six sandbag and one post/panel closure). The single post/panel closure was designed to close off flow from entering through Chase Street. According to the post flood report, the local sponsor lacked experience in both the planning and setting of the post/panel closure. It was noted they weren't sure when to start setting the closure and how it was to be put together in a timely manner. During the 2008 flood as the Little Calumet River was rising, the local sponsor was unable to set the post/panel closure and in a last ditch attempt tried to provide closure by placing a sand pile with plastic across the closure. This was unsuccessful as water poured into the interior through the Chase Street closure opening as the river rose above the sill elevation. This resulted in flooding of the interior, as shown in Figure H-5-21 where the closure is visible in the background. Consequences were limited primarily to economics as the interior flooding through the closure resulted in road damage and portions of the interstate being closed for a period of time (see Figure H-5-22).



Figure H-5-21. Flooding of Gary, Indiana at Chase Street Post/Panel Closure



Figure H-5-22. Flooding of Interstate in Gary, IN due to Failure of Post/Panel Closure

Following the flood, the local sponsor requested to permanently seal off the closure to avoid a repeat of what happened in 2008. The local sponsor felt there were multiple other access points to reach the area such that providing permanent closure at Chase Street would have little overall effect on traffic patterns. The local sponsor, working with an independent engineering firm, opted for large, removable concrete blocks to seal the closure, as shown in Figure H-5-23. These could be moved in an emergency, but it is unlikely they will ever be moved unless access to the area needs to be provided in the future.



Figure H-5-23. Semi-Permanent Concrete Block Wall at Chase Street (Gary, IN)

H-5.5.2 Soil Basket Failure – Winfield Pin Oaks Levee

Winfield Pin Oaks Levee is a locally constructed, locally operated/maintained levee that is active within the USACE PL84-99 program. The PL84-99 program is a program that allows the federal government to repair levees after flood damages as long as the levee is operated and maintained to a set of standards. The Winfield Pin Oaks Levee is located along the Mississippi River in Missouri just north of St. Louis. During the 2008 flood, the exterior levee protecting the agricultural area breached prior to overtopping along the southeastern section. The town of Winfield, MO is a small community located within the northwestern part of the interior area about 2 miles inland from where the breach had occurred. In an attempt to protect the town from

on-coming floodwaters, a combination earthen berm and soil basket levee was quickly constructed around the town with the use of National Guard troops. As the floodwaters reached the soil baskets and started to buildup, seepage started to emanate from under the soil baskets at the location of an 18” iron pipe that hadn’t been noticed previously. A secondary line of soils baskets was immediately placed landward in the area around the leaking pipe; however, the soil supporting the baskets quickly saturated and failed under the weight of the soil baskets that were topped with sandbags (see Figure H-5-24). While this wasn’t a closure system failure, it was a failure of a soil basket system that is commonly used for levee closures. The cause of the failure was the leaking pipe below the soil baskets that wasn’t noticed and saturated the soil supporting the baskets.



Figure H-5-24. Failure of Soil Basket System (Winfield, MO)

H-5.5.3 Sandbag Closure – Jackson Fairgrounds Levee

The Jackson Fairgrounds Levee is a federally constructed, locally operated/maintained levee located in Jackson, MS along the Pearl River. During a 1979 flood event, water from the Pearl River initially flooded the interior when it entered through an open street closure that was designated to be closed utilizing sandbags. According to the post flood report, there was confusion and overall lack of coordination between the various local and federal agencies as to who was responsible for setting the closure. While USACE was concentrating on keeping water from going over the levee embankment section, floodwaters flowed through the open roadway closure and began flooding the interior. The local agency responsible for operation and maintenance of the system didn't set the closure because they stated it wasn't shown as a requirement in the plans and operations manual; thus, neither group took the initiative to protect the interior from flooding by setting the closure resulting in significant interior flooding and economic damages as shown in Figure H-5-25. This event resulted in a congressional investigation to determine what actions caused the flooding and how it could be avoided in the future. The lack of setting the closure was determined to be one of the main causes of interior flooding along with performance issues associated with the sewer system.

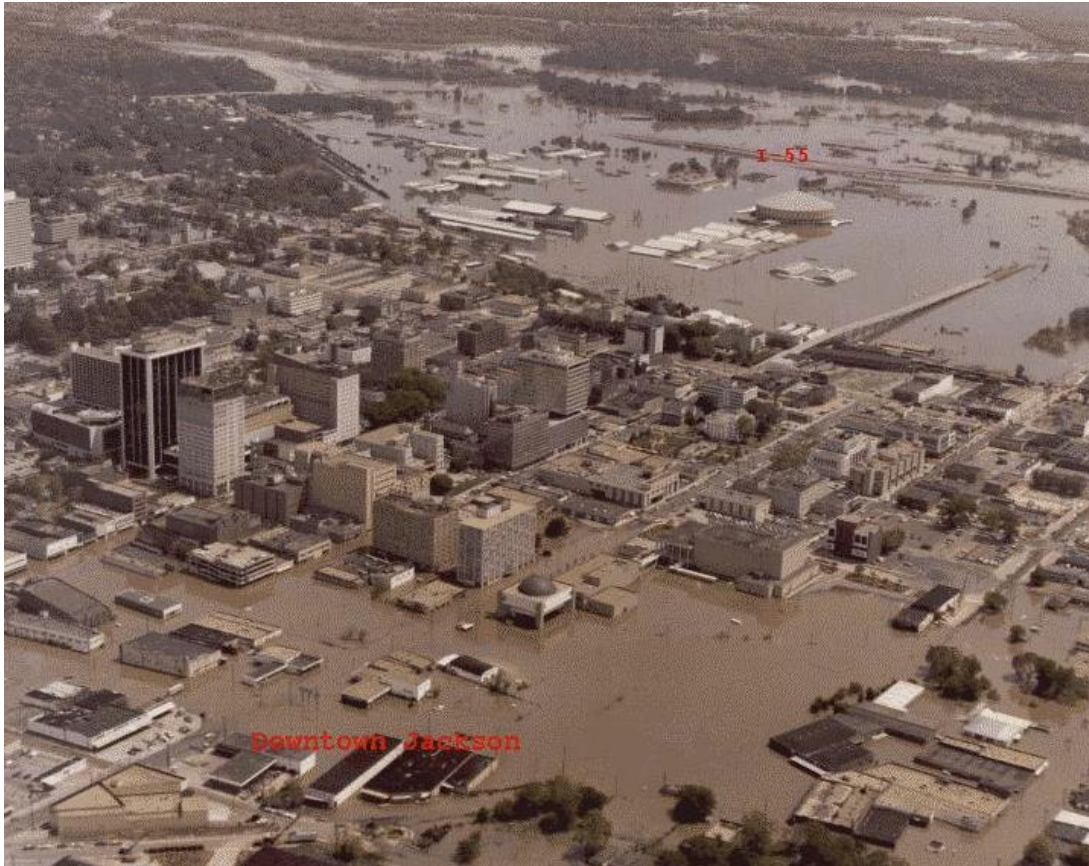


Figure H-5-25. 1979 Flooding of Jackson, MS

H-5.6 Levee Closure System Event Tree

A generic levee closure systems event tree is shown in Figure H-5-26. While each type of closure varies, the event tree is intended to reflect the potential paths to failure for most types of closures. There are a few types of closures where this type of event tree isn't applicable, such as culvert flap gate and duck bill closures, because they are designed to perform automatically on their own. Additionally, some of the branches may not be applicable for every type of closure such as ensuring all necessary parts and supplies are available, which wouldn't be required for simple moveable gate closure systems.

The initiating event (or branch) for all types of closures is associated with a river/stream elevation and/or discharge and corresponding forecast if applicable. Personnel responsible for determining when the closure needs to be set must be knowledgeable and well-versed on both the river conditions/forecast, as well as the time and manpower requirement for each closure on

their system. For large river systems, such as the Ohio or Mississippi, there are usually numerous river gauging stations and well-documented/calibrated forecasts that are available, as well as enough lead time to adequately prepare. The same is not the case for flashy river/streams that rise and fall quickly. Many times these are unregulated and ungauged so the personnel have to be much more cognizant of river conditions as it relates to anticipated precipitation in the region.

The next branch of the generic event tree relates to the availability and accessibility of the necessary parts to set the closure. Closures such as post/panel and stoplogs require a number of parts in order to be properly set and function adequately under load. These parts should be inventoried on a routine basis to ensure all are accounted for and in good condition. This is especially true for parts that aren't stored in a secure facility or haven't been inventoried in a long time (in more than five years).

If all the parts are accounted for, accessible, and in good working condition, the next branch relates to the operational experience of personnel actually setting the closure. Closure systems should be set in place on a minimum of a five-year interval either as part of training and/or flood fighting. This is very easy to do for some closures (swing gates, sluice gates, etc.), but others require an extensive effort in terms of both planning and manpower (post/panel, etc.). The operational experience of the crew setting the closure is usually a key risk factor when assessing the likelihood of failure for many closure systems.

The subsequent branch relates to the potential for condition or operational issues that could arise when setting the closure or after it has been set in place. Examples would be issues with the bearing sill, access issues, debris-related issues, etc. or anything that could potentially interfere with the successful placement and/or operation of the closure system. It has already been noted previously the issues with bearing sills for stoplog and post/panel closures. Other examples could be how the foundation for soil baskets or soil piles were prepared or any number of potential issues that may arise.

There are several opportunities to successfully intervene depending upon both the type of closure and type of river system. Successful intervention is much more difficult on flashier river systems because there usually isn't enough time to react and get the closure in place in the event of an

issue. As highlighted in Figure H-5-26, there are several ‘paths’ to successful placement and operation of the closure system and many of these involve some sort of intervention. Each case will be unique, but most of it comes down to timing and available manpower.

A few notes of clarification are provided herein with respect to the event tree on Figure H-5-26. Nodes 3 and 6 at the end of a few branches have been shown since they are repetitive branches meaning when you see node 3 at the end of the branch you would follow the path associated with node 3. The same is true when 6 is shown at the end of the branch. This was done in an effort to simplify the tree for this narrative. Also, estimating the probabilities for each tree should be done through elicitation. It is recommended that individuals with a good working knowledge of the levee and closure systems be involved with the elicitation. This could be as a ‘voting’ member helping establish the event tree estimates or providing key background information and answering technical questions from the panel estimating the values.

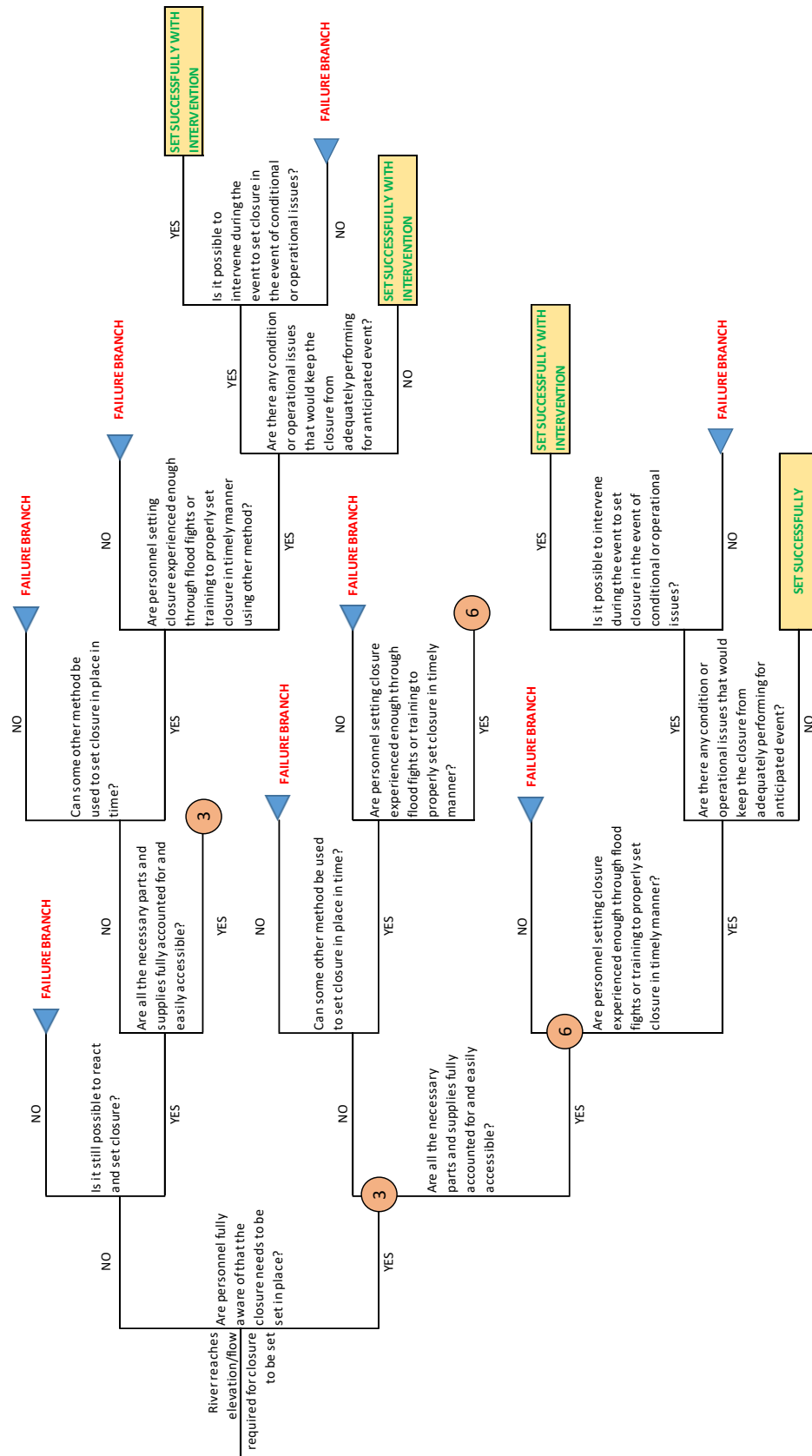


Figure H-5-26. Generic Event Tree for Levee Closure System

H-5.7 References

USACE Risk Management Center. "Levee Screening Tool Technical Manual," June 2011.

United States Comptroller General Office. "Improvements Being Made in Flood Fighting Capabilities in the Jackson, Mississippi Area," U.S. General Accounting Office Report, December, 1979.